Statistical Behavior of Formation Process of Magnetic Vortex State in $Ni_{80}Fe_{20}$ Nanodisks

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Magnetic vortices in magnetic nanodots, which are characterized by an in-plane (chirality) and an out-plane (polarity) magnetizations, have been intensively attracted because of their high potential for technological application to data storage and memory scheme as well as their scientific interest for an understanding of fundamental physics in magnetic nanostructures. Complete understanding of the formation process of vortex state in magnetic vortex systems is very important issue to achieve storage and memory technologies using magnetic vortices and understand intrinsic physical properties in magnetic nanostructures. In our work, we have statistically investigated the formation process of vortex state in permalloy ($Ni_{80}Fe_{20}$) nanodisks through the direct observation of vortex structure utilizing a magnetic transmission soft X-ray microscopy (MTXM) with a high spatial resolution down to 20 nm. We found a particular selectivity between the circulation sense of chirality and orientation sense of polarity for each other in the formation process of vortex state despite of their respective stochastic generation in statistical measurement. Dzyaloshinskii-Moriya (D-M) interaction in magnetic nanodisks, which is inevitably generated due to the breaking of inversion symmetry at surface/interface in magnetic thin layers, is mainly responsible for the experimentally witnessed selectivity between chirality and polarity in a formation of vortex structure.

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